BULLETIN 480 JULY, 1931

Breeding Experiments with Sheep and Swine

B. L. Warwick

OHIO
AGRICULTURAL EXPERIMENT STATION
Wooster, Ohio

The Ohio State University
3 6267 01222008 6

This page intentionally blank.

CONTENTS

This page intentionally blank.

BREEDING EXPERIMENTS WITH SHEEP AND SWINE

B. L. WARWICK[1]

INTRODUCTION

Detailed breeding experiments to study the inheritance of farm animals have been relatively meager because of the cost and the time involved. Such information as is available is of great value, and there is urgent need for more. The projects reported in this bulletin were initiated as long time experiments, each dealing with a separate character. Normally, these would be reported separately at the conclusion of a long period of study. However, owing to the change of personnel and to the fact that several of these projects have been discontinued, it seems advisable to bring the results together in one publication, even though many of the data are very meager and are of a preliminary nature, with the hope that they will be of value for future work.

Grateful acknowledgment is made of the aid extended by Mr. D. S. Bell in connection with the initiation and continuation of the sheep projects and by Mr. W. L. Robison with the swine work. Especial mention is made of the many helpful suggestions made by and the enthusiastic support of these projects by Dr. G. Bohstedt, former Chief of the Department of Animal Industry. The swine projects were transferred from the Wisconsin Station where the earlier phases of the work were conducted in cooperation with the Animal Husbandry Division of the U. S. Bureau of Animal Industry.

THE LAWS OF INHERITANCE

A discussion of the scientific basis of inheritance, which is called Genetics, cannot be included in this publication. The reader is urged to familiarize himself with the subject by study of some of the modern text books. Several of the most important of these are listed in the references (2, 6, 12, 29). However, as an aid to the reader who is not familiar with Genetic terms, a few of these terms will be defined or explained.

A *character* is the characteristic of the animal which is being studied. These are transmitted from generation to generation by *factors* or *genes* which are carried in the germ cells of the parents.

Phenotype is the appearance of the individual itself; while *genotype* is the factor complex of the individual.

[1]Now Animal Husbandman, Texas Agricultural Experiment Station.

Dominance refers to the property of one factor of a pair "dominating" or hiding the effect of the opposite factor when both are present in the same individual.

Recessive is the factor which may be hidden by its dominant mate.

Segregation is the separation of pairs of factors when the germ cells are formed in such a way that each germ cell has only one of any pair of factors.

Homozygous means that both of the factors in the individual are alike, sometimes called pure.

Heterozygous means that a dominant and a recessive factor are present together; also called *hybrid*, or impure.

Chromosomes consist of dark-staining material in the cell, which at certain stages of cell division show as rod-shaped bodies. The chromosomes are now believed to be the carriers of the factors.

Linkage means that the factors for two or more characters are carried on the same chromosome and tend to stay together in later generations.

P_1 stands for the first parental generation.

F_1 and F_2 represent the first and second succeeding, or filial, generations.

BLACK OF SHROPSHIRE AND MERINO SHEEP

In the common breeds of sheep in this country the approved color is white. In the fine-wool, long-wool, and some of the medium-wool breeds this includes the face and legs as well as the wool. The rest of the breeds have pigmented faces and legs, which complicate the color situation as will be discussed later. Most, if not all, of these breeds drop black lambs with disconcerting frequency, as such lambs must be considered highly undesirable, even in grade farm flocks. The black or grey wool produced by these animals sells at a sharp reduction. When packed with white fleeces, stray locks are likely to get with the good wool and lower the value of the whole sack.

Previous investigations.—Black lambs have been observed in many flocks of white sheep since the dawn of history. At one time purebred flocks of Merinos in Australia often included black lambs **(16)**, even though the black lambs were never used for breeding purposes. This led a few of the breeders to believe that this was the original Merino color and that if they bred for black they could improve their stock more rapidly. Several black flocks were established as early as 1877. It is reported that all of the offspring were black except for a white spot in the forehead and a white tip to the tail. It is said that in 1885 the black fleeces sold for double the price of the white Merino fleeces. However, this advantage seems to have been lost, and, as black wool sells at a reduced price, all such black flocks have been dispersed.

Fig. 1.—The three black sheep in this family were a great disappointment to their two white parents

For many years Dr. Alexander Graham Bell, the inventor of the telephone, maintained a flock of sheep at his summer home in Nova Scotia. He was interested primarily in the inheritance of the number of nipples and its relation to fecundity. In selecting multi-nippled sheep, some of the animals used for breeding purposes were black. Records were kept of the occurrence of black among the lambs. In 1905, Davenport (7) analyzed Dr. Bell's data from the color standpoint. At that time there were definite records on about 100 head, and he postulated a single recessive pair of factors as causing black. In 1924, Castle (4) reviewed the same and subsequent records up to the death of Dr. Bell and he came to the same conclusion as to the recessive factors involved. The three exceptions were believed to be either clerical errors or errors in classification due to the premature birth of lambs which should have been black.

The black of the Wensleydale breed has been investigated by Dry (9) and by Roberts and White (27), and has been shown to be recessive to white. However, the heterozygous individuals show very deep blue pigmentation of face, ears, legs, and skin. As this deep blue is highly favored in stud flocks, black lambs are regularly produced in most, if not all, of the stud flocks. This breed is not known to be present in this country. The data of Roberts and White (27) are adequate to show that this black is recessive to white, even though they record one exception to the expected black from black to black matings. White is considered to be the result of a factor which inhibits recessive black and so is dominant to this black. Roberts and White (27) also include a black ram of Southdown breeding in their study of the recessive black factor.

There are several breeds of sheep which are not common in the United States in which black is a common color; these include Welsh, Teackel, Karakul, and other breeds. Several investigators [reviewed by Roberts and Crew (26) and Roberts and White (28)] have given ample data to show that black is dominant in these breeds.

Brown (or red) is known in some of the breeds, but as it is rare in this country it will not be considered further in this paper. [Duck (10, 11), Ademetz (1), Roberts and White (27).]

It is common knowledge that black lambs have occurred in many of the good Shropshire and Merino flocks in this country where no black parents have ever been used. That this condition still exists has been verified by the writer, as will be noted in the report of the experimental work. In this country, the same situation exists, to some extent at least, in several of the other common breeds, if not in all of them. It is one of the serious problems of the purebred breeders today.

Dark fiber in white fleeces.—Several of the common breeds have dark markings on the head and legs. Among these breeds individuals will be found which have black wool fibers mixed with the white fibers of the fleece. When this is limited to a very small amount at the poll and at the junction of wool with the hair of the legs, it is probably of minor importance. However, individuals showing these dark fibers throughout the entire fleece have been observed, even in purebred flocks; this becomes a serious defect, as the wool is distinctly less valuable than wool free from the colored fibers. The occurrence of these fibers seems to have no relationship to the occurrence of black as such.

Nicols (25) made careful observations on the infantile or birth color and on the adult color of the same individuals and concluded that the lambs with very dark birth color were the ones which showed the most dark fibers and kemp as adults. (The Suffolk was the breed studied.) He also pointed out that the birth coat consists of two kinds of fibers, the outer of guard hairs which are shed before maturity and the under coat of true wool. In the dark colored lambs the outer coat is composed of black hairs and the inner coat has both black and white fibers. However, the black fibers are banded or black tipped instead of black from tip to base. This probably accounts for much of the difference in color when maturity is reached. Most of the dark-fibered grade Shropshire fleeces examined at this Station showed an appreciable quantity of black fibers mixed with the white. Most of these fibers were white at the base, while the distal half was black. A few matings were made between a grade dark-fibered ram and grade Shropshire ewes in the flock, but the data are too few to justify discussion.

The appearance of black wool.—Black fleeces have been studied from both purebred and grade Shropshire and Merino sheep. No fleece has been seen which had all black fibers. Usually, a certain percentage of the fibers are black from base to tip, others are black for part of the length and white for part. This white may be in the form of a band, or the base may be white and the tip half black. In addition, some of the fibers are white from base to tip. Boyd (3) has recently described the fibers of banded black fleeces. These fleeces showed fibers with more than one white band, as well as the different variations mentioned above. Wassin (34) includes an agouti factor in the analysis of his records. We are not certain whether any of our cases were the true agouti type of banded fibers.

Experimental matings.—The flocks of grade and purebred mutton sheep at the Ohio Experiment Station are not unlike many flocks with respect to the birth of an occasional black lamb. Among these occasional black lambs was a black ram lamb, sired by a purebred ram and out of a purebred ewe. This black ram lamb was reserved for breeding purposes and was mated with grade ewes in the flock to increase the number of sheep carrying the factor for black, so that the character could be studied. Other black rams produced in the experimental flock have also been used. In addition to the grade Shropshire ewes in the flock, other black females were purchased. These included six black ewes from grade Merino flocks and five black medium wool ewes. No black lambs have been dropped in the Ohio Station Merino flock. These medium wool ewes were purchased from the Cleveland stock yards and nothing is known of their breeding. Also, two black ram lambs were purchased from purebred flocks of Merinos. These Merino rams have not been used for breeding.

Matings of black to black.—Matings have been made of black rams to black ewes, resulting in 30 lambs. Of these, 28 were black or predominantly black. Most of them had more or less white fibers at the end of the tail and often on the poll. Some had much more white than this. This was true particularly of matings involving the black, Merino grade ewes. The Merino ewes usually have some white on the head, some about the neck, and a white ring

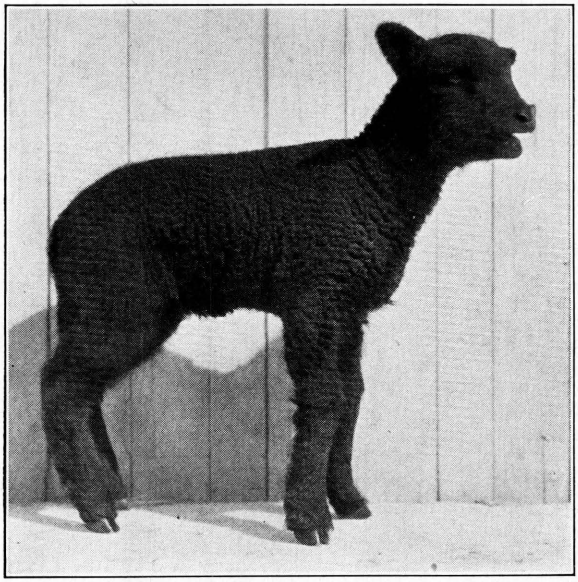

Fig. 2.—The recessive factor for black is contributed equally by both sire and dam

at each fetlock. One purebred Shropshire ewe which was black as a lamb, but faded markedly at maturity, dropped one lamb which had only a little black mixed with the white on the anterior half of the body, with the posterior part mostly black. The same ewe produced two other lambs which were typical blacks. The two clear-cut exceptions were sired by a pure Shropshire black ram and out of black, medium-wool ewes which were purchased at the Cleveland stock yards. One of these, dead due to difficult parturition, was a typical white lamb. The other was white except that the head and legs and infantile spotting on the body were reddish or tan rather than black. Also the long, outer, guard hairs of the lamb coat were very numerous, long, and persisted for several months before being shed. Nothing is known about either of these black dams except what their appearance and progeny suggest. There are three possibilities to explain the occurrence of these exceptions. There may have been accidental matings to these ewes in addition to the controlled matings. The dams may carry dominant black instead of recessive as is assumed. There are some Karakul sheep in Ohio; so it is not impossible to have an infusion of that breeding in some commercial flocks. It is also possible that there are additional factors sometimes present which counteract the action of the black factors. Only further carefully controlled breeding tests can determine which is the true explanation.

Matings of black to heterozygous and of heterozygous to heterozygous.—Matings were made where one parent was white, but known to have produced one or more black lambs, and the other parent was black. Twelve lambs resulted from these matings; five were black and seven were white. This is very close to the expected monohybrid back-cross ratio which is six to six. Ten other black lambs have been dropped during the period of observation and nine others are noted in the records of the flock in such way that they may be used. It would be desirable to get the ratio of black to white lambs from these matings, where both parents were white but heterozygous. However, our information is not as complete as we might wish owing to the question as to the heterozygosity of certain of the other rams used. Also, the ewes were often withdrawn from this type of mating after dropping one black lamb and either bred to a black ram, or to a white ram which had not been definitely proved to be heterozygous. Study of such definite records as we have shows that these matings produced 38 white and 19 black lambs. This is a deviation of $4\frac{3}{4}$ from the expected 3 to 1 ratio and actually is 2 to 1. This particular combination will occur on the average 4.14 times per 100 trials with 57 individuals in each trial on the basis of chance due to the probabilities involved in sampling alone. The deviation is only 2.1 times the probable error which shows that we may expect a deviation as great or greater in 15.67 times out of every 100 trials. This is equivalent to odds of 5.38 to one. As this list of progeny is neither an experimental group nor a random sample, it is surprising that the numbers are even this close to the theoretical 3 to 1 ratio.

Conclusions.—We believe that our observations confirm the conclusions of previous workers that the black of these breeds is recessive. Even though there are complicating factors, this color factor is without doubt recessive, and it is produced by the one principal pair of factors.

Practical considerations.—This knowledge can be put to immediate practical use by the breeder in the elimination of black from his flock. The following rules should help the breeder:

1. Every ram which is the sire of one or more black lambs carries the factor for black along with the factor for white and transmits this factor for black to half of his offspring. He should be discarded as soon as it is known that he carries the factor for black.

2. Every ewe which is the mother of one or more black progeny is known to carry the factor for black the same as the ram. Both the sire and the dam have to carry the recessive factor whenever the progeny is black. Such ewes may also be discarded from the stud flock. However, if it were always known that the ram was pure for white, this would not be necessary.

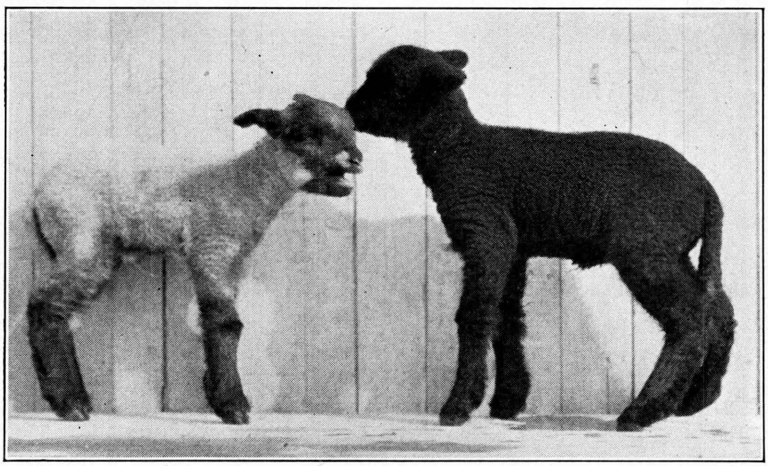

Fig. 3.—Dissimilar twins (one black and one white) from white parents

3. In high class stud flocks the ram might be tested for black before being mated to high class stud ewes. This test would consist of breeding the ram to ten or more black ewes. If a single black lamb should result, it would be proven that the ram carried the factor for black. The possibilities of such test matings are discussed in a later section of this bulletin.

CHALK-FACE IN MERINO SHEEP

"Chalk-face" or "frosted-face" are terms used to designate the presence of stiff, coarse, dull, white hairs on the faces of Merino sheep. Their appearance is in sharp contrast to the soft, fine, smooth, silk-like hairs desired and normally found on the faces of high-class Merinos. Breeders commonly call the desirable appearance "velvety-nose."

It has been the opinion of some Merino judges that the fineness of the hair on the nose is directly related to the fineness of the fleece. Also, it was thought that the chalky hairs present in the adjacent parts of the wool might be of considerable economic importance. However, since the "chalky" character is present in some of the finest fleeced Merinos, it cannot be considered a direct index to this character. Furthermore, as the chalky hairs in the fleece appear to be limited to those portions of the fleece removed as skirtings, its economic importance seems to be negligible.

The much desired soft, silk-like hair must, therefore, be considered as a "nicety" or trade-mark of the breed and, as such, should be preserved and purified. To this end, a knowledge of the inheritance of the defect is desirable as an aid to its elimination (33).

Results of breeding trials.—In order to study the mode of inheritance of this character, a ram which showed these chalky hairs and two of his "chalk-faced" sons were mated to ewes showing the defect and to a number of ewes free from the defect. Among the 20 lambs resulting from the chalk female to chalk male matings 13 were chalky and 7 were clean; from the chalky male to clean female matings 14 lambs resulted, 3 of which were chalky and 11 clean. Among several hundred matings of rams and ewes which were entirely free from chalky hairs in the Ohio Station Merino flock, only one lamb has been observed among the progeny which showed the chalk-face character.

These data indicate that this undesirable character is due to dominant factors. It is very unlikely that any of the chalky parents were homozygous. Table 1 is based on this assumption, as well as on the assumption that a single pair of dominant factors is responsible.

TABLE 1.—Chalk-faced × Chalk-faced Merino Sheep

	Chalky hairs present	Chalky hairs absent	Total
Expected (3-1)	15	5	20
Actual	13	7	20
Deviation	−2	+2	....

The character is not due to simple recessive, else all the progeny, Table 1, would show the character. These figures show that its inheritance can be explained on the basis of a single pair of dominant factors.

The number of chalky individuals resulting from mating the chalk-faced rams to clean ewes falls short of the expected 50 per cent, as shown in Table 2. However, we know from expansion of the binomial $(\frac{1}{2} + \frac{1}{2})^{14}$ that the probability of getting this particular combination in trials with 14 individuals is .0222. This means that (based on chance alone), on the average, among 100 groups of 14 individuals each, two or more groups would show this particular combination, or once in every 45 such groups (a ratio of 1 to 44) we could expect to get this combination. The probability of getting a deviation from the expected as great as or greater than this is .0574, which is equivalent to odds of 16.42 to one. This shows that this deviation can be accounted for on the basis of the probabilities involved in sampling. Accordingly, we will consider that the character is due to one pair of dominant factors.

TABLE 2.—Clean-faced × Chalk-faced Merino Sheep

	Chalky hairs present	Chalky hairs absent	Total
Expected (1-1)	7	7	14
Actual	3	11	14
Deviation	—4	+4	....

Conclusions.—There can be no doubt that this character is due to dominant factors rather than recessives. Our data suggest that only one pair of dominants is present. This should make its elimination easy. Rigid selection seems to be the only tool necessary to use against this undesirable character.

ENTROPION OR TURNED-IN EYELIDS IN LAMBS

Entropion (also called entropium) is the technical name for the turning in of one or more of the eyelids. This is known to occur in several species of mammals, including man. Among domestic animals it has been recognized as a surgical problem in horses, dogs, and sheep, and a definite technic has been described for operation when needed (37). In sheep the writer would distinguish two types, infantile and Merino entropion.

Infantile entropion.—This is found in new-born or very young lambs. The afflicted lamb has "sore eyes" due to one or more of the eyelids being turned in so that the eyelashes irritate the eyeball, stimulating a copious flow of tears. If this irritation continues for a considerable time, the eyeball becomes injured, may become opaque, ulcerated, and may even burst as a result. We have seen lambs with both eyes blind as a result of this condition. On the other hand, a great many of the afflicted lambs make a spontaneous recovery in from one to 10 days. If the eyelid is pulled outward into its normal position several times a day recovery is more likely. Stubborn cases may need to have the affected lid held in the normal position by a thread. This is stitched through the skin of the lid and in the skin at the base of the lid. Removal of a piece of skin is resorted to when other methods fail. Occasionally, an eyelid remains turned in for months and possibly years with no apparent injury. Infantile entropion has been observed as a common condition in the Shropshire, Merino, and Rambouillet breeds. It also occurs in other breeds. Skidmore (30) reported its occurrence in the Shropshire and Rambouillet breeds, but not in the Oxfords, Hampshires, and Southdowns kept at the Nebraska Experiment Station. The more open-faced breeds, such as the Cheviot and Dorset Horn, seem to be less troubled with entropion than those breeds with more closely wooled heads. Its frequent occurrence in the breeds with more face covering would suggest that it is associated with thick wool covering of the face. This view is held by some practical sheep men, Green (14). In regard to its frequency, Williams (36) stated in 1926: "Probably it is not guessing too high to say that 5000 sheep men east of the Rocky Mountains will find just such cases in their sheep barns this spring, as heretofore." The writer knows of no reason why it should not be as prevalent in the western states as in those east of the Rockies. Jakob (19), discussing entropion (presumably infantile) in his text on ophthalmology of domestic animals, states that heredity has a definite rôle, especially in dogs. Hobday (17) also considers it definitely hereditary in dogs.

Merino entropion.—This type of entropion in sheep appears after the lamb is several weeks or months of age. It usually affects the upper, but may affect both the upper and lower, lids. It becomes more accentuated as the fleece gets long, and it tends to be less noticeable after shearing. This type of entropion seems to be due to a wrinkling of the skin of the eyelid and has been observed by the writer only in the Merino type of sheep. The number of body wrinkles does not seem to be a direct index, however, as the most heavily wrinkled Merinos in the experimental breeding flock are free from the trouble. It seems more likely that the condition is the result of the chance location of a small skin wrinkle reaching the base of the eyelid. Small skin wrinkles being a characteristic of Merinos, it is easy to understand the frequent occurrence of this type of entropion. So far as we are able to determine, this type of entropion has not been distinguished in the literature. It seems unlikely that there is any relationship between infantile and Merino entropion, except that either or both may be found in Merino sheep. Owing to the extreme variability of the expression of this type of entropion, our data are not complete enough for analysis of the possible inheritance of the character. It seems likely that if heredity has a very large rôle, it is indirect; that is, the effect is incidental to the general result of factors having to do with wrinkling in general.

Detailed observations of infantile entropion.—Observations were made on the lambs at birth and at frequent intervals until they were weaned. Complete observations were made on the purebred Merino, the purebred Shropshire, and the grade Shropshire flocks of the Ohio Experiment Station during the nursing period of 1927. Similar observations were made on the lambs out of a mixed bunch of ewes and sired by a purebred Shropshire ram. During the lambing seasons of 1928 and 1929, complete detailed observations were only made on the lambs dropped in the experimental breeding flock. The frequency of the trouble is shown in Table 3.

TABLE 3.—Frequency of Entropion in the 1927 Lamb Crop

Group	Lambs with turned-in eyelids		Lambs with normal eyelids		Totals
	Number	Per cent	Number	Per cent	
Purebred Merinos	16	19.0	68	80.9	84
Purebred Shropshires	8	34.7	15	65.2	23
Grade Shropshires	6	17.6	28	82.3	34
Combined purebred and grade Shropshires	14	24.5	43	75.4	57
Mixed group	26	34.3	50	65.7	76
Total	56	25.8	161	74.1	217

In addition to the above observations, seven of the Merino lambs developed typical Merino entropion as they grew older.

In the fall of 1927 the experimental breeding flock was assembled as a separate unit. It was drawn largely from the purebred Merino and the grade Shropshire flocks at the Station and included a large proportion of older ewes. The 1928 lamb crop in this group was sired by five rams, four of which were born during the spring of 1927. All four of these rams had been closely observed as lambs and had never had turned-in eyelids. The other ram was a yearling which had not been checked as a lamb for entropion. The 1929 lamb crop included a few lambs sired by one of the ram lambs which showed entropion. The occurrence of entropion in the experimental flock is shown in Tables 4, 5, 6, and 8. All of the detailed observations for this defect are brought together in Table 7.

TABLE 4.—Frequency of Infantile Entropion in Experimental Group, 1928

Breed	Entropion		Normal		Totals
	Number	Per cent	Number	Per cent	
Merino	2	9.09	20	90.90	22
Shropshire	8	38.09	13	61.90	21
Merino × Shropshire	0	....	1	100.00	1
Totals	10	22.72	34	77.27	44

TABLE 5.—Frequency of Infantile Entropion in Experimental Group, 1929

Breed	Entropion		Normal		Totals
	Number	Per cent	Number	Per cent	
Merino	2	10.00	18	90.00	20
Shropshire	12	37.50	20	62.50	32
Merino × Shropshire	0	....	4	100.00	4
Totals	14	25.00	42	75.00	56

TABLE 6.—Combining Tables 4 and 5 Showing the Frequency of Infantile Entropion in Experimental Group in 1928 and 1929

Breed	Entropion		Normal		Totals
	Number	Per cent	Number	Per cent	
Merino	4	9.52	38	90.47	42
Shropshire	20	37.73	33	62.26	53
Merino × Shropshire	0	....	5	100.00	5
Totals	24	24.00	76	76.00	100

TABLE 7.—Combining Tables 3 and 6 Showing the Frequency of Infantile Entropion in All the Lambs Studied

Breed	Entropion		Normal		Totals
	Number	Per cent	Number	Per cent	
Merino	20	15.87	106	84.12	126
Shropshire	34	30.90	76	69.09	110
Mixed group	26	32.09	55	67.90	81
Totals	80	25.23	237	74.76	317

TABLE 8.—Frequency of Entropion in Experimental Flock, Seasons of 1928 and 1929

Sires	Entropion		Normal		Totals
	Number	Per cent	Number	Per cent	
734S	2	14.28	12	85.71	14
2004S not entrop	1	25.00	3	75.00	4
2006S not entrop	8	61.53	5	38.46	13
47G not entrop	5	26.31	14	73.68	19
35G not entrop	2	50.00	2	50.00	4
43G entrop	2	50.00	2	50.00	4
501M	1	5.26	18	94.73	19
642M	2	33.33	4	66.66	6
703M not entrop	0	....	7	100.00	7
744M not entrop	0	....	3	100.00	3
753M not entrop	1	14.28	6	85.71	7
Totals	24	24.00	76	76.00	100

These tables show that infantile entropion is more frequent in the flock of grade and purebred Shropshires than in the Merino flock. Its distribution, according to the sires, is given in order to show that entropion occurs among lambs by most of the sires used. The numbers are too small to warrant any weight being given to the nonoccurrence of entropion among the progeny of two of the rams. Among these sires, seven were definitely known to have had normal eyelids, one had the left lower eyelid turned in for a very short time, and the other three had not been checked for this trouble as lambs.

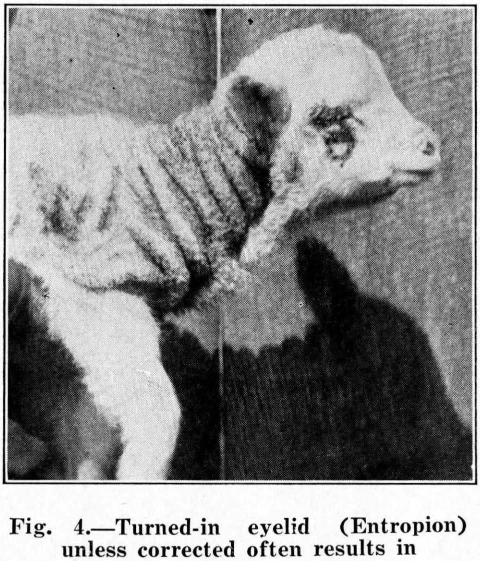

Fig. 4.—Turned-in eyelid (Entropion) unless corrected often results in blindness

Only twelve lambs have been observed in the flock from matings where both parents had been checked for entropion as lambs. In each case, neither parent had shown the defect as a lamb. Three of these lambs had entropion, while the other nine were normal. Unfortunately, no records are yet available of matings of entropion to entropion.

Discussion.—The primary purpose of placing on record the above observations is to call attention to the great frequency of the trouble in these breeds of sheep. Also, it is of interest that most of the afflicted animals made spontaneous recovery; on the other hand, a few lambs with the trouble were very seriously affected. In fact, two deaths were observed as a direct result. No treatment was given the lambs included in these observations as we wished to learn more as to the effects of this trouble on the animals. The condition is easily relieved, even in bad cases; yet it is a nuisance at lambing time to bother with lambs so afflicted. We are led to suspect that it is due, at least in part, to heredity; yet our data do not lend themselves to the definite answer of this question. If these notes should help to stimulate further observations and breeding tests, their purpose will have been fulfilled.

CRYPTORCHIDS OR RIDGLINGS IN SHEEP

"Cryptorchid" and "ridgling" are the terms used to designate male animals in which one, or both, of the testicles remain in the abdominal cavity. When the testicle is formed during fetal development, it is first located just back of the kidney. Normally, it descends through the abdominal wall by way of the inguinal canal and becomes permanently located in the scrotum. In the pig, this descent or migration of the testicle is complete by the 100th day of fetal life (31). So far as we know, no comparable work has been done on the normal descent of the testicle in the lamb. However, its descent is normally complete by the birth of the lamb, if not before. After birth, in the pig and the lamb the testicle increases in size more rapidly than does the inguinal canal. This prevents the return of the testicle into the abdominal cavity. In the rabbit and other rodents, however, the inguinal canal continues large in comparison to the size of the testicle. Also, the homologue of the cremaster muscle is present in the form of a complete cylinder of muscle fibers around the spermatic cord and testicle. This is called the conus inguinalis. This structure makes it possible for these animals to retract the testicle into the abdominal cavity.

Previous investigations.—Cryptorchidism is a defect observed in many species of mammals. It has long been known that the undescended testicles of the horse did not contain functional germinal epithelium or spermatozoa. Dollar (8) credits Gurlt (1838-1858) as being the first to discover this fact. That it did not interfere with coitus was well known. When only one testicle was retained, the one which had descended normally was usually perfectly normal and was entirely adequate for reproduction. These observations have been verified innumerable times in the horse, as well as in other animals.

Griffiths (15) first showed, in 1893, by experiment that replacement of a normal testicle in the abdominal cavity, without disturbance of the blood supply, led to the same degenerate histologic picture as found in sporadically occurring cases of cryptorchidism. Crew (5) suggested that this degenerate condition of the retained testicle was due to a temperature difference between the abdominal cavity and the scrotum. Moore (24) and associates proved this by a series of brilliant experiments.

Ridglings have been observed in many herds of swine and flocks of sheep in which no ridgling sires have ever been used. The occurrence of ridglings is not uniform in all herds and flocks; certain sires seem to produce more of these than others. These observations would suggest the possibility of the character's being inherited and its being transmitted as a recessive. Ridglings seem to be especially prevalent in goats. Gist (13) stated in 1923: "So far as I know, there is no purebred flock of Angora goats in America that are wholly free from this defect—that is, occasionally a ridgling kid will be dropped when only normal or apparently normal sire and dam are mated."

Wolf (38) reported in 1923 the breeding of a "one-seeded" Angora goat to Angora does. He raised 24 males, one of which was a ridgling. Twelve of the F_1 females were bred back to their sire; the 16 males produced included five ridglings. This report would point toward the inheritance of the defect. Lush, Jones, and Dameron (22) have been continuing the study of this character in Angora goats for a number of years and report that it is unquestionably hereditary, but they have not yet come to a definite conclusion as to the factors involved. McKenzie (23) has recently accumulated some data pointing to the inheritance of cryptorchidism in swine. Other authors including Crew (6), Dollar (8), and Hobday (17, 18) state that cryptorchidism is hereditary but they do not present any data.

Observations at the Ohio Station.—Among the several flocks of sheep at the Station, cryptorchidism has been observed. Also, we know from conversation with Merino breeders that this defect occurs in the Merino breed. It is believed by some that polled

Merinos are more likely to be ridglings than are those with horns. During recent years, the ridgling rams dropped in the Station flock of Shropshires have been sired by one ram or by some of his sons or grandsons in the experimental breeding flock. Also, in one instance, the same dam has dropped two ridgling sons.

Breeding results.—Seventeen lambs have been sired by two ridgling rams. These include five males sired by one of these rams and four by the other. Only one ridgling is included among these nine males. However, the dam of this one ridgling is the only one among the dams of these males which had any history of cryptorchidism. She is the dam of another ridgling, sired by a normal ram.

The above observations tend to point to the inheritance of this character in sheep, but have not been carried far enough to make any analysis of the factors possible.

"HIGH-STEPPING" PIGS

A condition somewhat simulating "stringhalt" as seen in horses has been observed for a number of years among pigs on feeding tests. The affected animals have been observed at both the Wisconsin and Ohio Stations. The animals walk jerkily with the hind legs and usually lift the feet very high. The feet may be jerked as high as the back. In very severe cases, the pigs have difficulty in walking and so remain down much of the time. Normal pigs in the same lot abuse the affected animals if they are not separated. Loss in flesh is usually noticed and, in some cases, this reaches a state of emaciation. However, actual death from the trouble is rarely, if ever, known to occur. A partial recovery usually takes place after several months.

The cases observed among the swine at the Ohio Station were all sired by one normal boar. The trouble was found among pigs in lots receiving a wide range of rations. It was found among pigs fed out-of-doors on good forage, as well as among those fed indoors. These facts led to the belief that it was not a nutritional disease and that it probably had some hereditary basis.

Breeding results.—In order to test the possibility of inheritance, two affected gilts were retained for breeding purposes. No affected boars were available, as the affected males had been castrated before they showed the trouble. These two affected females were bred back to their normal sire. One of them raised four pigs, all of which showed some disturbance which interfered with their locomotion. However, this occurred when they were only a few weeks of age and only continued a short time, after which recovery was practically complete. This is in direct contrast to the history of the cases in the general herd. These cases in the general herd always showed the trouble not earlier than 14 weeks of age, and the very marked interference with the locomotion always continued for a much longer time. Accordingly, it is impossible to draw conclusions from the appearance of these pigs. The other gilt only raised one pig and it was normal. The same affected dam, however, raised 7 normal pigs, sired by a boar of entirely different breeding.

Discussion.—These data are too meager to prove whether this defect is inherited or not. The observations of the trouble in the general herd point to the probability of its being inherited. If so, it cannot be due to dominant factors. Both the frequent "out cropping" of the defect in the general herd and the production of the litter of seven normal pigs out of the affected sow and sired by the non-related normal boar are arguments against the possibility of dominant factors having to do with the defect. If the defect is inherited, as is strongly suspected, it is probably due to some combination of recessive factors. On the basis of our present knowledge of this defect, it would be advisable to eliminate any boar from breeding service if any of his progeny definitely show this defect.

THE INHERITANCE OF BLACK IN SWINE

Previous investigations.—The inheritance of black of Poland-China and Berkshire swine, when crossed with the red breeds, Duroc-Jersey and Tamworth, has been reported by several investigators, [Lush (20), Wentworth and Lush (35), Wright (40), and Warwick (32)]. The results may be summarized as follows: The F_1 progeny carry a body color of some shade of red or sandy color. Scattered over this red or sandy body color are numerous black spots of varying sizes. The total amount of black present is never as great as that of the black parent of the cross. It may be said that it is never more than about half as extensive, and it is often less. In F_2 progeny, about 75 per cent of the animals carry one or more black spots; while 25 per cent lack any black in the hair or skin. The amount of black present on the spotted F_2 animals varies from a single very small spot to a predominance of black. The body color in F_2 varies from red through the various shades to sandy and cream and to practically white. Wentworth and Lush interpret these results on the basis of one pair of factors for black, two for reds and sandies, and, in addition, a diluting factor linked to black acting on one of the factors for sandy. Warwick has presented data tending to confirm the hypothesis of a single pair of factors being responsible for the presence of black. This interpretation assumes that multiple factors regulate the amount of black when the factor for black is present.

Wright (40) has reviewed the literature and interprets the inheritance of black in these breeds upon a somewhat different basis. He assumes that there are a large number of minor factors which extend the black and dilute the red in the black breeds mentioned, with the opposite set of factors restricting the black and intensifying the red in the red breeds. He does not include a major pair of factors as being responsible for the presence of black.

Results of breeding trials.—Since the previous report (32), the present writer has made further observations upon the segregation of black in various generations beyond the F_2 where the original cross was between the Poland-China and Duroc-Jersey breeds. All of the data, including those already published, are brought together here and summarized.

One hundred and thirty-one F_1 progeny were born and were examined at birth. Most of these were the result of mating one Duroc-Jersey boar with Poland-China females. One litter of six represents the reciprocal cross. The body color between the black spots varied from nearly white to red. Black was present on every individual. All matings of heterozygous parents have been grouped and their progeny classified in Table 9. These include all F_2, as well as other matings, in which it is known, either from the parentage or from the progeny, that both parents are heterozygous.

TABLE 9.—Distribution of Black in Swine. All Matings of Heterozygous × Heterozygous Parents

	Black present	Black absent	Total
Actual	161	55	216
Expected (3 to 1)	162	54	216
Deviation	−1	+1	....

All back-cross matings of Duroc-Jersey and of non-black segregates to known heterozygotes are listed in Table 10.

TABLE 10.—Distribution of Black in Swine. All Matings of Heterozygous Black × Non-Black (Reds and Sandies)

	Black present	Black absent	Total
Actual	123	139	262
Expected (1 to 1)	131	131	262
Deviation	−8	+8	P.E. = 5.46 $\frac{\text{Dev.}}{\text{P.E.}}$ = 1.4+

Matings of non-black segregates have been made and the young examined at birth. One hundred and twenty-nine of these were non-black, while five of them had definite black spots. These five pigs were from four different mothers. They cannot be the result of accidental matings to heterozygous spotted boars, as no boars of this kind were kept during the time that these litters were sired. Non-black segregates were also mated to purebred Duroc-Jersey boars. Among 90 pigs from this mating, there were two which showed a small black spot on each. Two hundred and seventy-four purebred Duroc-Jersey pigs have been born in the same herd and have been subjected to the same detailed observation at birth. Of these, only one showed any black and this consisted of only a few black hairs on the poll at birth. However, the writer has observed a number of purebred Duroc-Jersey and Tamworth swine which definitely showed a small amount of black in each case.

Some evidence may be gathered from the data as to the proportion of homozygous to heterozygous dominants in the F_2 generation. On a single factor hypothesis, this should be 1:2. Altogether, 11 litters of pigs were produced by nine black-spotted F_2 females; seven of these litters were sired by a black-spotted F_2 boar. The other four were by a red boar. The progeny from six of the nine females tested included both black-spotted and non-black individuals in each litter. This test proves definitely that the six sows were heterozygous. Two of the other sows had, respectively, seven and eight pigs by the black-spotted boar. All of these pigs were black-spotted. The remaining sow raised one litter of four by the black-spotted boar and one litter of nine by the red boar, all of which were spotted. This indicates that these three sows may be homozygous for black. The black-spotted F_2 boar used is shown by the above data to be heterozygous. Thus, nine females and one male of the F_2 generation were tested, and six of the females and the one male proved to be heterozygous and three of the females homozygous for black. This is a ratio of 3:7, which is very close to the expected 1:2.

Discussion of results.—In the presentation of the above data, the hypothesis of a single pair of factors for black has been assumed. The figures fit the theoretical expectation very well in F_1, F_2, and back crosses. However, in the mating of non-black segregates, either *inter se* or with the purebred Duroc-Jersey, a few exceptions are seen. We believe that the hypothesis can be amplified to some extent and these exceptions explained. Incidentally, it will also bring the hypothesis of Wright and the present one nearer together. Undoubtedly, the amount of black, when present, is regulated by a number of factors. Probably, these are typical multiple factors of a quantitative nature. Accordingly, a curve might be constructed on the basis of the amount of black present on the different individuals which show any black in the F_2 generation. At one end of this curve would be individuals with about the same amount of black as found in the Poland-China parental generation. We have records of individuals which closely approached this in the F_2 generation. At the other end of the curve would be individuals which carried only a very small amount of black. In addition to these, we would theoretically expect to have a very few which carried the factor for black, but did not show it because of the homozygous combination of the quantitative factors which restrict the amount of black to zero. This number would be very small. Assuming ten pairs of factors we would only expect an average of one such case in 1024 from the F_2 population. In back crossing, generations beyond the F_2 might show a few more, depending upon the chance genotypes of the red or other non-black parents used. Also, we might assume that some of the non-black individuals genotypically carried black-spotting factors but missed getting it phenotypically in embryonic development. This kind of situation has been demonstrated by Wright (39) in tri-colored guinea pigs. It would seem reasonable to believe that if this took place to any great extent that we would have many more pigs showing black among the progeny of the non-black segregates, when bred *inter se*. The multiple factor hypothesis applied to the animals which carry one or both of the major pair of factors for the presence of black can account for the few exceptions found.

Another line of evidence is the occurrence of homozygous females in F_2, as shown by F_3 and back-cross matings. Only relatively few of the F_2 were adequately tested, but the fact that a few were found among the population predominantly heterozygous is good indication that there is a single pair of dominant factors responsible for the presence of black.

In brief, the present data seem to warrant the following hypothesis: There is one major pair of dominant factors responsible for the presence of black. When this factor is present, the amount of black is determined by multiple factors. Combinations of these factors, at one extreme, produce animals with as much black as the black parental type. Combinations at the other extreme result in individuals with little, or even with no, black present, even though the factor for black is present. This accounts for the few exceptions when non-black individuals are bred *inter se*.

Owing to the heterozygous nature of the stocks used in regard to the reds and dilutions of red, it does not seem profitable to try to analyze the data from that standpoint. If it had been possible to retain very dilute (that is, "synthetic white") segregates for further test matings, this could have been done. Individuals of this kind have appeared from time to time in the F_2 and later generations. However, as this herd of swine has been used primarily for other genetic experiments of economic importance, it has never been possible to put a "synthetic white" boar into service for color study only. "Synthetic white" animals for test purposes would be of great value in analyzing the factors for red and its dilutions.

Summary.—Data from 1109 pigs were analyzed in a study of the inheritance of black from Poland-Chinas. Poland-China and Duroc-Jersey swine were crossed. One hundred and thirty-one F_1 individuals were produced, all of which had some black. Two hundred and sixteen progeny of matings of heterozygous to heterozygous, 262 progeny of heterozygous to non-black, 134 progeny of non-black segregates to non-black segregates, 90 progeny of non-black segregates to pure reds, and 274 pure Durocs were studied at birth. The ratios of black to absence of black conform very closely to the expected, on a single-factor hypothesis. There were eight individuals with black present when non-black was mated with non-black. These are explained by the action of multiple factors which determine the amount of black when the factor for black is present. No data are given on the factors for red and its dilutions.

Conclusions.—1. Poland-China black is due to a single pair of dominant factors. 2. When the factor for black is present, its amount is determined by multiple factors. 3. The action of the multiple quantitative factors produces a very few pigs which are non-black, but which carry the dominant factor for black.

INHERITANCE OF SCROTAL HERNIA IN SWINE

Hernias, or ruptures, of swine are so common that scarcely a swine raiser has escaped experience with them. The two most common kinds are scrotal, or inguinal, hernia and umbilical, or navel, hernia. Scrotal hernia consists of an enlargement of the scrotum by loops of bowel. Although the anatomic differences of the sexes necessarily limit the occurrence of scrotal hernia to the male, females sometimes are seen which have inguinal hernia, which would be comparable. So far as our observations go, we have no reason to believe that there is any hereditary relationship between the two. The loops of bowel pass through the opening of the abdominal wall (inguinal canal) with the spermatic cord which connects with the testicle. Umbilical, or navel, hernia is formed by loops of intestine passing through the abdominal wall at the umbilicus, or navel, but without a break in the skin.

Breeding tests to determine whether scrotal hernia was heritable in swine were initiated by the writer at the Wisconsin Experiment Station in 1922, where they were carried on in cooperation with the U. S. Department of Agriculture until 1926, when they were transferred to the Ohio Experiment Station and there continued until 1929. Detailed study was made of the economic importance of the defect, the physical factors involved, and the time of appearance of scrotal hernia. A full account of these aspects of the problem, as well as the results of the earlier years of the breeding tests, was published as a Research Bulletin from the Wisconsin Station (31). Accordingly, only a summary of the part covered by that bulletin will be presented here, with a discussion of the breeding results to the conclusion of the project.

As a result of the study of records obtained from Experiment Station herds, it was found that inguinal or scrotal hernia affected 1.68 per cent, and umbilical hernia affected 0.60 per cent, of the male pigs raised to weaning. Among the females raised in the same herds, 1.16 per cent had hernias, practically all of which were umbilical.

The internal opening of the inguinal canal was found to be triangular in shape and always large enough to permit of hernia formation. The internal opening of the membranous covering of the spermatic cord (which membrane is continuous with the peritineum lining the abdominal cavity) varies in size. This and a low degree of tensity of the membrane (*tunica vaginalis*) are the physical causes of scrotal hernia.

Study of embryological material showed that the descent of the testicle was complete by the 100th day of fetal life. This allows 12 to 18 days for the newly formed *tunica vaginalis* to attain strength enough to withstand the abdominal pressure after birth. Neither the canal formed by the *tunica vaginalis* nor the inguinal canal contract after the descent of the testicle. However, the former increases relatively slowly in size as compared with other parts, particularly with the testicle. As a consequence, by the time of birth, the testicle is too large to be drawn back from the scrotum through this canal in spite of the fact that the space between the layers of the *tunica vaginalis* of the scrotum and spermatic cord remain in communication with that of the peritoneal cavity

Scrotal hernia occurs more frequently on the left side than on the right. It may disappear spontaneously, even after several months' duration. However, this is not of very frequent occurrence. Scrotal hernia may first appear when the pig is from one day to one month of age. It is never present at birth and only rarely appears for the first time in animals more than one month of age.

TABLE 11.—Summary of the Occurrence of Hernia in Pigs Raised to One Month of Age in the Experimental Herd

	Generation of selection for scrotal hernia							Total
	1	2	3	4	5	6	7	
Number of pigs	132	163	122	125	106	24	7	679
Number herniated	11	41	34	32	29	11	2	160
Per cent herniated	8.33	25.15	27.86	25.60	27.34	41.66	28.57	23.56
Number of male pigs	66	92	69	70	57	11	5	370
Number males herniated	11	39	31	31	27	10	2	151
Per cent males herniated	14.28	42.39	44.92	44.28	47.37	90.90	40.00	40.81
Per cent males scrotally herniated	14.28	42.39	43.47	44.28	47.37	81.81	40.00	40.27
Number males umbilically herniated	0	0	1	1	0	1	0	3
Number females umbilically herniated	0	2	2	0	2	1	0	7

Breeding tests.—In order to put the question of the inheritance of hernia to experimental test, sows have been bred to scrotally herniated boars. Seven generations have been bred with herniated sires in each case. Five litters sired by a normal boar have been raised in the 4th, 5th, and 6th generations, bringing the total number of pigs raised in this work to 701. Most, but not all, of the parent females used had some rather close relationship to herniated boar pigs. Later generations were sired by either one of these herniated boars or by some of his herniated descendants in the herd. Table 11 shows the incidence of hernia in each of the seven generations represented. A study of the table shows that the percentage of scrotally herniated males jumped to 14.28 per cent in one generation of selection and to over 42 per cent in the second. The percentage was hard to raise further in later generations, as it was difficult to find dams among the animals which seemed to be true breeding or homozygous for this character.

Figure 5 shows a comparison of the percentages of male pigs herniated when various degrees of selection have been made. The first column (A) represents the occurrence of scrotal hernia in the various Experiment Station herds where no selection against the defect has been made, except elimination of actually herniated animals. Most of the parent stock of our experimental herd came from the Animal Husbandry herd of the University of Wisconsin. The incidence of scrotally herniated pigs in this herd for the spring and fall crops of 1922 and the spring crop of 1923 is shown in (B). During the period, most of the pigs were sired by two boars, Giant Fashion and College Buster Clansman, which were high producers of herniated pigs. After these two sires were eliminated, the incidence of scrotal hernia dropped, as shown in (C). Scrotal hernias in the first to sixth generations of selection for hernia in the experimental herd are represented by (D) to (I), inclusive. Because of the very small number of pigs in the seventh generation, it is not included in the graph. This clearly shows that there is inheritance of a tendency to the occurrence of scrotal hernia in boar pigs.

Tentative hypothesis.—In the previously mentioned bulletin, a tentative hypothesis was advanced to account for the mode of inheritance of this character. This postulated the presence of scrotal hernia as dependent upon the presence of two pairs of recessive factors in homozygous condition. The affected animal would carry the factors hh h′h′. Sows of the same genotype would be normal because of the anatomic differences due to sex. On this basis, the mating of herniated boars to normal sows of Hh H′h′ would produce three normal males to one herniated male. The expectation from such a mating would be:

GENOTYPES	PHENOTYPES (male)	PHENOTYPES (female)
Hh H′h′	Normal	Normal
Hh h′h′	Normal	Normal
hh H′h′	Normal	Normal
hh h′h′	Herniated	Normal

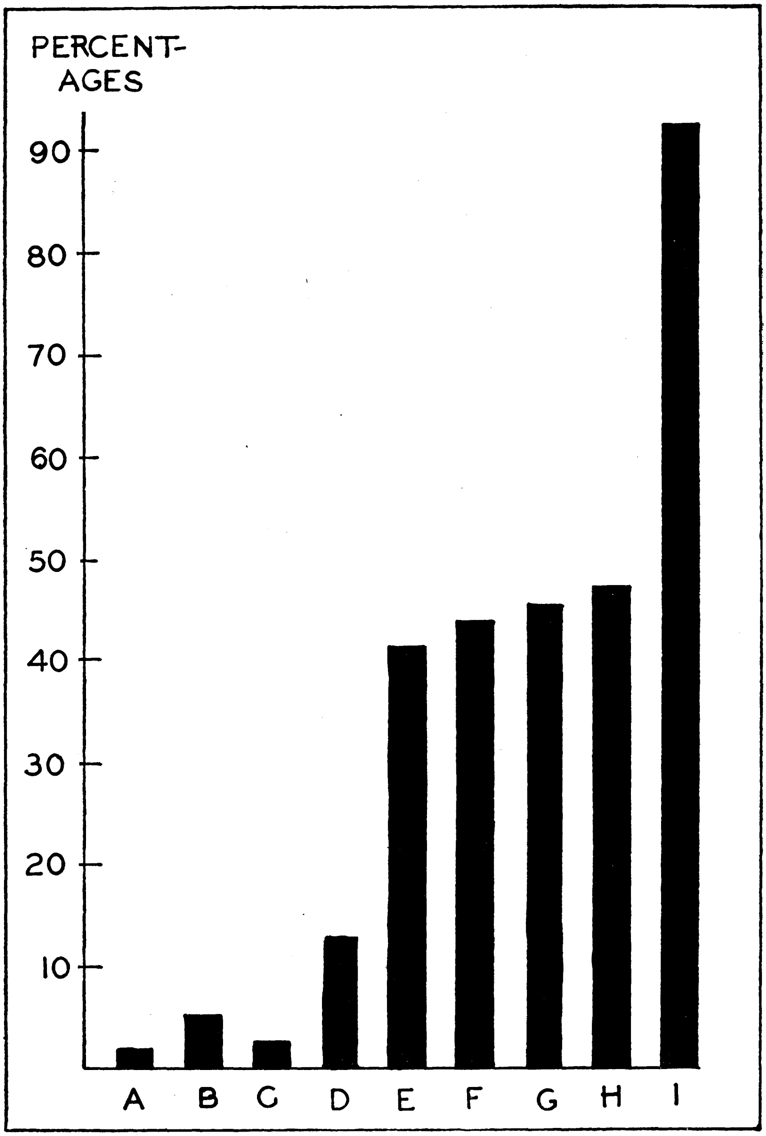

Fig. 5.—Scrotal Hernia in Swine

A. Experiment Station herds, no selection except elimination of herniates.
B. Parent herd, first period, no selection except elimination of herniates.
C. Parent herd, second period, after eliminating two boars.
D. First generation selection for hernia.
E. Second generation selection for hernia.
F. Third generation selection for hernia.
G. Fourth generation selection for hernia.
H. Fifth generation selection for hernia.
I. Sixth generation selection for hernia.

Two types of matings of herniated boars to normal females could produce herniated boar pigs in the proportion of one herniated to one normal. These matings are:

(1) hh h'h' males × Hh h'h' females

GENOTYPES	PHENOTYPES (male)	PHENOTYPES (female)
Hh h'h'	Normal	Normal
hh h'h'	Herniated	Normal

(2) hh h'h' males × hh H'h' females

GENOTYPES	PHENOTYPES (male)	PHENOTYPES (female)
hh H'h'	Normal	Normal
hh h'h'	Herniated	Normal

At the time this hypothesis was advanced, no females had been shown to be homozygous by breeding test. It was hoped that such sows might be located for further breeding tests of the hypothesis. Seven sows produced from three to five herniated pigs each and no normal males, but the numbers of progeny are not adequate for a conclusive test. An attempt has been made to classify all of the male progeny of the different sows according to whether they should be in the 1—0, 3—1, 1—1, or the 0—1 group. This was based upon both the numbers represented in the particular mating and upon the performance of daughters, when such records were available. In this way, 122 were placed in the 3—1 progeny group and 185 in the 1—1 progeny group. The 3—1 group included 92 normals and 30 herniates, which is as close as physically possible to the expected. In the 1—1 group, there are 85 normals to 100 herniates, which is a deviation of 7½ from the expected. The probable error, when the population is 185, is ±4.59. The deviation of 7½ is only 1.6 times the probable error. A deviation as great as this may be expected in 28 out of every 100 trials and so is not significant. Obviously, the progeny of the seven sows noted above as possibly homozygous are not included in either of these groups. Also, three other sows are excluded because of lack of normal pigs, even though they only had one or two boar pigs each. The number of sows subjected to these breeding tests is of necessity small. Study of the probable segregation within the litters shows that, with these small numbers, it is within the limits of normal chance distributions for some homozygous sows to have been eliminated when the gilts were selected each time. Accordingly, it seems reasonable to expect that, if it had been possible to continue the testing of these seemingly homozygous sows and their progeny, a homozygous group would have been revealed. In the absence of further testing, the proposed hypothesis seems the most reasonable explanation of the known facts. Certainly the defect is due to some combination of recessives. More than one pair of recessive factors are present. The number of pairs of factors cannot be large. Two pairs explain our data better than more or fewer factors. Accordingly, the tentative hypothesis is accepted until such time as further evidence shall indicate necessary changes.

Practical considerations.—The following procedures should aid greatly in the process of elimination of this defect from the herd:

1. No boar should be used which is, or ever has been, afflicted with scrotal hernia. This includes animals in which the rupture has disappeared naturally, as well as operated animals. Whether hernias would appear among the immediate offspring of any such boar would depend upon the hereditary makeup of the females with which he was mated. In any case, all of his offspring would carry some of the factors responsible for scrotal hernia. This would make it very probable that ruptures would appear in later generations whenever individuals of certain hereditary makeup (even though themselves normal) happened to be mated together.

2. Any normal boar which has sired one or more ruptured pigs should be discarded. Such a boar will transmit factors for scrotal hernia to half, or more than half, of his offspring and, hence, tend to carry it on in the herd, even though the sows to which he is mated should be entirely free from the taint.

3. Breeding stock should not be selected from sows which have produced one or more scrotally ruptured pigs. The same reasons apply here as in the case of the male.

4. Litter mates to scrotally ruptured boars should not be retained for breeding purposes, especially the males. Some of these will probably be free from the hernia factors, but it would require extensive breeding tests to determine which ones these are.

5. Elimination of all of the progeny of boars which have been known to sire scrotally ruptured pigs would also be advised where especial effort is being made to eliminate scrotal hernia.

The rules which have been suggested provide a logical method of reducing, and in time eliminating, scrotal hernia from a herd of swine. In very valuable herds of swine, the elimination of the defect can be hastened by testing the prospective herd sires before regular use. This would be done by breeding him to females which are known to carry factors for hernia. The appearance of a single scrotally herniated pig among the offspring would show that the sire carried the factors and he should be rejected from the breeding herd. This test is discussed more fully in a later section of this bulletin. Since the boar is the parent of many more offspring than any one sow, his influence on the breeding herd is far greater than that of any individual female. For this reason, it is desirable to take especial care in his selection.

GENETIC TESTS AS AN AID TO BREEDING

A study of our improved herds of farm animals shows that wonderful advancement has been made, and perfection of form and performance has been so nearly reached that an inspection of the best animals would lead one to think that no more advancement is possible. However, even in the best purebred herds and flocks, we find many disappointing progeny. It is not possible to tell by looking at any pair of animals whether they will "nick" well until they are tried. Of course, the better the animals and the richer the pedigree, the greater the chance of superior progeny.

There are at least two aims in the breeding of high class purebreds. One is the production of a few animals that will excel any preceding animals of the same species or breed. The other is the purification and unifying of the stock to the point where culls cease to appear. The first is a laudable ambition in itself; yet we believe the second is even more desirable. In this, the herd or flock should be brought to a level where 100 per cent of the progeny would be as good as the best 25 per cent of the present time. This would mean that the limit of variation would be small. This is the slow result of ordinary selection with rigid culling.

There are numerous specific defects, or undesirable characters, which appear too frequently in most herds and flocks. These are usually due to the appearance of recessive factors that have been carried along generation after generation in the normal, superior individuals, that have been used for parent stock. It is impossible to determine by inspection which animals carry these recessive factors, as such factors are concealed by the normal dominant factors.

Sometimes the undesirable recessive factors have been carried down through the generations from mixed stock used in the formation of the breed or from animals in its earlier history when these particular characters were not discriminated against to the same degree as at present. In many cases no animals that showed these characters have ever been used for breeding. This means that there have been mutations in the stock, which, owing to their recessive nature, did not show up until the factors became distributed through a large portion of the well-bred animals.

It is possible to test prospective sires to determine whether or not they carry specific recessive factors. This test can be made by breeding the prospective sire to animals carrying the recessive factors. The appearance or nonappearance of the recessive characters in the progeny would determine accurately whether or not the prospective sire carried these factors. A recessive character cannot show up in the first generation when only one of the parents carries the factor.

The specific mode of procedure when making the test will depend upon whether the undesirable recessive character is due to one or several pairs of factors and upon the kind of females it is possible to use. When the defect is due to one pair of recessive factors, seven to ten offspring out of females showing the recessive character would be sufficient. If one or more individuals among the progeny showed the recessive character, it would indicate definitely that the male used carried the factor for that recessive along with the dominant. If seven offspring in the test appeared and none showed the recessive character tested for, it would be almost a certainty that the male did not carry the recessive factor. In this case, the chances as to the accuracy of the test would be 127 to 1 that it was accurate. Increasing the number of progeny to ten would bring the odds to 1023 to one.

Of course, it would also be possible to test the females, but the number of offspring from each breeding female is so small that the animal would likely be past her period of usefulness by the time the test was completed.

While these tests are not now in use by breeders of livestock, they are not new. They have been used in testing in the laboratory for hundreds of recessive characters in the small animals and insects. The use of this kind of a test by breeders of livestock would be the direct application of science to their work and would be another step in the purification of the breeds.

One of the recessive defects that can be tested for is black, as seen in Shropshire and Merino sheep, which is discussed in another section of this bulletin. Black lambs sometimes crop out in good flocks where black parents are never used. In these cases both white parents carry the recessive factor for black. On the average, one-fourth of the lambs from this kind of mating will be black. The appearance of the rams and ewes used gives no inkling that they carry the factors for black; yet the ewes in such matings drop black lambs to the extent of 25 per cent.

Where one parent is black, the color of the lambs depends upon whether or not the white parent carries the recessive factor for black along with the dominant factor for white. If the white parent does carry the factor for black, half of the lambs will be black and the other half will be white. In case the white parent does not carry the factor for black, every lamb will be white even though one parent is black. This is the test for the black factor in a white ram, as described above.

To repeat, the appearance of a single black lamb, means that both the sire and the dam of that lamb carry the factor for black. This is true whether either parent is black or not.

Scrotal hernia as reported in this bulletin is due to recessive factors. Owing to the fact that more than one pair of factors are operative, more progeny would be necessary in testing sires than would be the case if there were only one pair of recessives. Also, the masking of the defect in the female would make it necessary to know the parentage of the test females. A group of females sired by a scrotally herniated boar would be satisfactory. If it were possible to select from this kind of animals sows which had produced a high proportion of herniated pigs, they would be desirable. In this case, the normal boar to be tested should be bred to enough of these sows to produce about 25 to 30 boar pigs. If a single scrotally herniated pig appeared, it would show definitely that the sire carried the factors for hernia. If the sows used in making the test were out of a herd pure for absence of hernia, but sired by a herniated boar, it would take more progeny to make the test certain. If all the sows were doubly heterozygous, it would take about 70 male progeny to prove beyond a doubt that the boar tested did not carry the hernia factors. Groups of sows could be produced for test purposes which would only require 15 male progeny for a critical test.

Similar tests could be carried out to determine whether sires carry the factors for the cryptorchid (ridgling) character, but more experimental work is needed before the specific procedure can be outlined.

Horns of cattle are inherited in the same way as black in sheep. In the polled breeds, such as the Polled Hereford and Polled Shorthorn, it is often desirable to know whether a prospective herd bull is pure (homozygous) for the polled character. He could be tested by breeding to ten horned cows. If one horned calf resulted, it would show that he carried the factor for horns. Absence of horned calves would demonstrate that the bull was pure for polled.

Horns in Toggenburg goats have been shown by Lush (21) to be inherited in the same way as those of cattle, and the same test can be applied.

The cost of carrying out test matings for prospective stud sires, as discussed above, is the main objection to their use. The breeder who could use these tests to best advantage would justly hesitate to maintain a group of off-color or defective animals for test purposes. However, he could well afford to go to some expense to have his most likely prospects tested before mating them extensively to high class females. It should be possible to have certain breeding farms devoted exclusively to the testing of prospective sires. These could be cooperative or private enterprises if rightly conducted. Undoubtedly, when the demand becomes great enough, some means of carrying out these tests will be provided.

REFERENCES CITED

1. Adametz, L. 1917. Studien über die Mendelsche Vererbung der wichtigsten Rassenmerkmale der Karakulschafe bei Reinzucht und Kreuzung mit Rambouillets. Bibliotheca Genetica 1:1-258.

2. Babcock, E. B. and Clausen, R. E. 1918. Genetics in relation to agriculture. (McGraw-Hill Book Co., N. Y.) 675 pages.

3. Boyd, Evlyn. 1930. Colour-banding in fleeces. Jour. Textile Institute 21 (6):T287-T292.

4. Castle, W. E. 1924. Genetics of the multi-nippled sheep. Jour. Heredity 15:75-85.

5. Crew, F. A. E. 1921. The cause of the aspermatic condition of the undescended testis. Thesis, Edinburgh University. (Original not seen).

6. Crew, F. A. E. 1925. Animal genetics. (Oliver and Boyd, London) 420 pages.

7. Davenport, C. B. 1905. The origin of black sheep in the flock. Science, N. S. 22:674-675.

8. Dollar, J. A. W. 1912. Regional veterinary surgery. (J. F. Hartz Co., Toronto) 1131 pages.

9. Dry, F. W. 1924. The genetics of the Wensleydale breed of sheep. I. The occurrence of black lambs. Jour. Genetics 14:203-218.

10. Duck, R. W. 1921. Mendelism in fur sheep crosses. I. Jour. Heredity 12:410-413.

11. Duck, R. W. 1922. Mendelism in fur sheep crosses. II. The zygotic cause of red lambs when fur sheep are crossed on Longwools and their grade offspring. Jour. Heredity 13:63-68.

12. East, E. M. and Jones, D. F. 1919. Inbreeding and outbreeding. (J. B. Lippincott Co., Philadelphia) 285 pages.

13. Gist, A. 1923. Urges elimination of ridgling. Angora Journal 12:(3) 21.

14. Green, J. D. A. 1926. Curing sore eyes in young lambs. Breeder's Gazette. Apr. 8, 1926. p. 437.

15. Griffiths, J. 1893. The structural changes in the testicle of the dog when replaced within the abdominal cavity. Jour. Anatomy and Physiology 27:483.

16. Harrowell, R. H. 1917. Black Merinos in Australia. National Wool Grower 7:(2) 13-14.

17. Hobday, F. T. G. 1914. Castration and ovariotomy. Ed. 2. (W. and A. R. Johnston, Edinburgh and London) 162 pages.

18. Hobday, F. 1923. Cryptorchidism in animals and man. Proc. Royal Soc. Med. 17:3-14.

19. Jakob, H. 1920. Tierärztliche Augenheilkunde. (Richard Schoetz, Berlin) 600 pages.

20. Lush, J. L. 1921. Inheritance in Swine. Jour. Heredity 12:57-71.

21. Lush, J. L. 1926. Inheritance of horns, wattles, and color in grade Toggenburg goats. Jour. Heredity 17:72-91.

22. Lush, J. L., Jones, J. M., and Dameron, W. H. 1930. The inheritance of cryptorchidism in goats. Texas Agr. Exp. Sta. Bull. 407.

23. McKenzie, F. F. 1930. Information to the author.

24. Moore, C. R. 1926. The biology of the mammalian testis and scrotum. Quart. Rev. Biol. 1:4-50.

25. Nicols, J. E. 1927. On the occurrence of dark fibres in the Suffolk fleece, with particular reference to the birth coat of the lamb. Jour. Textile Institute 18:395-413.

26. Roberts, J. A. F. and Crew, F. A. E. 1925. The genetics of sheep. Bibliographia Genetica 2:263-286.

27. Roberts, J. A. F. and White, R. G. 1930. Colour inheritance in sheep. IV. White, recessive black, recessive brown, badger-face pattern and reversed badger-face pattern. Jour. Genetics 22:165-180.

28. Roberts, J. A. F. and White, R. G. 1930. Colour inheritance in sheep. V. Further observations on dominant black. Jour. Genetics 22:181-190.

29. Sinnott, E. W. and Dunn, L. C. 1925. Principles of Genetics. (McGraw-Hill Book Co., N. Y.) 431 pages.

30. Skidmore, L. V. 1928. Entropion in lambs. Jour. Am. Vet. Med. Ass'n. LXXIII. N. S. 26:624-627.

31. Warwick, B. L. 1926. A study of hernia in swine. Wis. Agr. Exp. Sta. Res. Bull. 69.

32. Warwick, B. L. 1926. Inheritance of black in swine. Jour. Heredity 17:251-255.

33. Warwick, B. L. and Bell, D. S. 1929. Inheritance of chalk-face in Merino sheep. Proc. 1928 meeting Amer. Soc. An. Prod. pp. 38-39.

34. Wassin, B. 1928. Genetik des Schafes. I. Vererbung der Farbe und Abzeichen. Arbeiten der Zentralstation für Genetik der landwirtschafliches Volkskomissariat der R. S. F. S. R. No. 2. pp. 1-68. Moscow. [Russian with German title page and German summary.]

35. Wentworth, E. N. and Lush, J. L. 1923. Inheritance in swine. Jour. Agr. Res. 23:557-582.

36. Williams, G. P. 1926. Curing sore eyes in young lambs. Breeder's Gazette, Apr. 8, 1926. p. 437.

37. Williams, W. L. 1917. Surgical and Obstetrical operations. (Macmillan Co., N. Y.) 240 pages.

38. Wolf, C. M. 1923. Ridglings prove bad policy. Angora Journal 12:(2) 25.

39. Wright, S. 1917. Color inheritance in mammals. V. The guinea-pig. Jour. Heredity 8:476-480.

40. Wright, S. 1918. Color inheritance in mammals. VIII. Swine. Jour. Heredity 9:33-38.

This page intentionally blank.